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Special Challenges of Transboundary Coordination in Restoring Freshwater Ecosystems

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I. INTRODUCTION

The title for this conference on "Transboundary Freshwater Ecosystem Restoration" is deceptively compact. Several complex but related issues of institutional design are compressed into that short phrase. First, there is the challenging theme of transboundary coordination. The difficulties of crossing political and property boundaries to achieve coherent ecological goals are longstanding topics of debate in environmental law at both the domestic and international levels. Beyond that central issue, the conference title also raises three more implicit topics for discussion: how do modern understandings of ecosystems affect choices about the configuration of institutions to transcend existing boundaries? Do freshwater resources present special issues or opportunities for insights into means for coordinating wise decisions across boundaries? Finally, does the goal of restoring rather than simply protecting existing resources pose particular problems for efforts to organize ecological decision-making?

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This article explores a few key aspects of these themes, drawing from recent literature on development of institutional frameworks for ecological decision-making. This article begins with an overview of some characteristic problems created by boundaries in the ecological context by exploring the reasons behind the frequently expressed need for transcending, bridging, or overcoming jurisdictional barriers. The discussion then turns to institutional challenges raised by advances in the scientific understanding of ecosystems, and the difficult task of correlating human boundaries with ecological ones. It then considers the application of these themes in the freshwater context, and the particular conundrums that arise when the goal is to rework landscapes to achieve ecological restoration. Finally, this article argues that while existing jurisdictional boundaries may indeed pose barriers to reaching wise ecological decisions, the configuration of new and more effective institutional frameworks depends in crucial ways on new boundary-making efforts.

II. THE TRANSBOUNDARY PROBLEM

A. *Common Pool Resources and the "Tragic" Effects of Boundaries*

Other papers for this conference deal in depth with the implications of sovereign borders for interactions at the international scale. Here, it is worth pausing to more broadly reflect on the generic problem of jurisdictional boundaries in natural resource management. Whether the line is a political border between countries, states, or municipalities; a boundary between government agencies that manage natural resources in public ownership; a demarcation between the regulatory jurisdictions of administrative agencies; or a property line between adjoining private landowners; a boundary represents a division of decision-making authority over resources among different forms of human organization. Boundary lines are manifestations of broadly defined property regimes.[1] They mark allocations of authority over resources among organizations that include powers of exclusion.[2] Boundary lines also denote potentially differing forms of governance within organization borders.[3]

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1. Property regimes are broadly conceived here to mean resource management institutions that include public property, common property, and private property, whether expressed through formal laws or informal norms. *See* Susan Hanna, Carl Folke, & Karl-Göran Mäler, *Property Rights and the Natural Environment, in* RIGHTS TO NATURE: ECOLOGICAL, ECONOMIC, CULTURAL, AND POLITICAL PRINCIPLES OF INSTITUTIONS FOR THE ENVIRONMENT 1, 4-5 (Susan S. Hanna et al. eds., 1996) [hereinafter RIGHTS TO NATURE]; *see also* Robert C. Ellickson, *Property in Land*, 102 YALE L.J. 1315, 1319 (1993) (discussing customary norms as aspects of a "land regime").

2. *See generally* Thomas W. Merrill, *Property and the Right to Exclude*, 77 NEB. L. REV. 730, 731-32 (1998) (discussing exclusionary authority as central to the meaning of property).

3. *See* Fikret Berkes, *Social Systems, Ecological Systems, and Property Rights, in* RIGHTS TO NATURE, *supra* note 1, at 87, 97-101 (summarizing regulatory mechanisms for controlling uses and users found in different types of property regimes).

When water, fisheries, and other renewable migratory resources extend across boundaries, concerns about fragmentation in human organization arise. As often observed, the dynamic and interactive qualities of "common pool" resources make meaningful compartmentalization difficult, and demand some sort of integrated means for coordinating human activities. Where ecological interdependencies create complex repercussions across space and time, the resource will have greater value to the society at large if somehow managed "as a whole" or as a "going concern."[4]

The freshwater ecosystems that we are considering here have the paradigmatic characteristics of renewable common pool resources.[5] Portions of the resources may be removed for human use and consumption without disrupting the renewal of hydrological and biological patterns, but the renewability of the underlying system of resources depends upon sustaining complex interconnections and interactions.[6]

In these situations, when interconnected ecological phenomena extend beyond jurisdictional authority, the fundamental criticism of boundaries is related to the unwillingness or inability of autonomous organizations to coordinate their activities so as to take effects beyond their borders into account.[7] In essence, those exploiting the resources are accused of causing ecological harm while hiding behind the protective shield of their boundary lines.

The concern that decision-makers inside a boundary will be unable to perceive ecological repercussions outside a boundary line, or that they will be unwilling or unable to control repercussions when they do perceive them, is often compared to a "tragedy of the commons."[8] The classic narrative of a "tragedy" narrowly depicts self-interested and autonomous individual actors who are motivated to exploit resources ahead of others, and who inexorably overuse resources in an unregulated open-access commons to their joint detriment. Their failure to come together to establish property rights or regulatory mechanisms for excluding excessive exploitation and managing human activities leads to wasteful destruction of otherwise renewable resources. The commons lacks meaningful boundaries, aside from the exclusionary capacities of individuals to

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4. *See* Carol M. Rose, *Energy and Efficiency in the Realignment of Common-Law Water Rights*, 19 J. LEGAL STUD. 261, 291-92 (1990) (discussing why resources such as rivers have greater value when they are kept intact rather than divided among individual owners).

5. *See, e.g.*, Elinor Ostrom & Edella Schlager, *The Formation of Property Rights*, *in* RIGHTS TO NATURE, *supra* note 1, at 127, 129-30 (outlining key characteristics of common pool resources).

6. *See* Elinor Ostrom, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 30-33 (1990) (distinguishing the resource system from the flow of resource units subject to appropriation and use).

7. *See* Eyal Benvenisti, SHARING TRANSBOUNDARY RESOURCES: INTERNATIONAL LAW AND OPTIMAL RESOURCE USE 23 (2002) (observing that political borders that disregard boundaries of natural resources, and fail to take environmental and hydrological characteristics into consideration, preclude efficient outcomes).

8. Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243, 1244 (1968).

grab, use, and profit from the resources that they capture. The ensuing tragedy results from the absence of mechanisms for taking external effects into account.[9]

In the transboundary setting that is the focus here, the shared resources do not lie outside all boundaries. In this regard, they are not open-access in the sense of being "open to all." The adjoining jurisdictions have an ability to control access by others to the shared resources within their joint boundaries. Where migratory resources flow in a particular direction, as in the case of a river system, the upstream jurisdiction is also in a superior geographical position to limit access by the downstream jurisdiction--for example, when it builds an impoundment to capture water resources.[10]

Transboundary resources are not simply bisected by political borders, but typically segmented by property and administrative lines. We are not dealing with the autonomous and unconnected individuals of a simple tragedy-of-the-commons narrative, but rather with well-organized groups of people who have already achieved various forms of organization and management through existing economic and political forums that are reflected in a multitude of boundary lines.

Nevertheless, the concept of a "tragedy" resonates with observed problems of collective action in transboundary ecosystems. The problems arising from actions by fragmented organizations are akin to those that arise from the uncoordinated actions of independent individuals. In essence, autonomous entities grab and impair resources without taking ecosystem-wide impacts into account. Eric Freyfogle has called this phenomenon of fractured control a "tragedy of fragmentation."[11]

Despite the existence of multiple boundary lines, and explicit assertions of organizational ownership and control, important aspects of the resources nevertheless lie outside available systems of monitoring, accounting, and coordination. Although the existing political and property institutions may define many facets of authority over the resources in question, the benefits of coordinated action across boundaries are not realized.[12] In a sense, this is an

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9. Carol M. Rose, *Given-Ness and Gift: Property and the Quest for Environmental Ethics*, 24 ENVTL. L. 1, 4-7 (1994) (examining the reasons why tragedies of the commons occur in the management of environmental resources).

10. *See* Thomas W. Merrill, *Golden Rules for Transboundary Pollution*, 46 DUKE L.J. 931, 970 (1997) (distinguishing collective action problems in dealing with pollution of transboundary resources from those relating to pollution of resources in open-access commons outside sovereign control, and further distinguishing problems of unidirectional and reciprocal pollution).

11. Eric T. Freyfogle, *The Tragedy of Fragmentation*, 36 VAL. U. L. REV. 307, 322-31 (2002).

12. Fragmentation of authority can produce overuse of resources in an open-access commons, or it can produce underuse in an "anticommons," where boundaries prevent owners from engaging in beneficial activity without the cooperation of the others. *See* Michael A. Heller, *The Boundaries of Private Property*, 108 YALE L.J. 1163, 1167 (1999). *But see* Lee Anne Fennell, *Common Interest Tragedies*, 98 NW. U. L. REV. 907, 911-12 (2004) (describing the range of "common interest tragedies" that can result from fragmentation of entitlements, and questioning distinctions that have been drawn between tragedies of the commons and anticommons). In the context of concerns about transboundary ecosystems, one might argue that the fragmentation created by boundary lines both causes the overuse of resources, and establishes exclusionary barriers that prevent use of the ecosystem as a functioning whole.

acknowledgement that seemingly well-defined property rights are in fact uncertain and incomplete, and that important factors of great value to the society at large have simply been left out of the system for defining, regulating, and transferring rights. Existing boundary lines then merely serve to validate the uncoordinated and shortsighted behavior of groups and organizations, instead of providing a means for recognizing and protecting important ecological values.[13]

For example, when water withdrawals along a river deplete the water flow needed to sustain wetlands across a boundary, a fundamental criticism is that the actors on either side of the boundary lack workable political and market institutions for considering the damaging environmental effects of the upstream uses, and for limiting, allocating, and transferring water rights in light of the diverse ecological and economic values at stake. This criticism does not merely mean that upstream water uses are having harmful effects downstream, even though that certainly may be a significant concern. Some trade-offs between consumptive uses of water by people and instream uses of water by other people or organisms would presumably occur even in a well-coordinated system of unified governance. To say that something "tragic" has occurred means that different and ecologically wiser decisions would have been reached through better institutional arrangements.

Why then do adjoining jurisdictions in these circumstances often fail to come together to pursue joint interests by creating an integrated resource management regime? If the number of entities involved were not too large, one might imagine that a clear boundary line could simply provide the starting point for negotiations and transactions leading to the creation of a coordinated framework.[14] Nevertheless, to varying degrees depending on the locations and circumstances, a range of transaction costs, strategic behaviors, and cognitive failures can contribute to difficulties in developing integrated regimes for sharing resources in transboundary ecosystems.[15]

The inability of unconnected actors to respond to information about external impacts creates an especially prominent set of problems.[16] Myopic decisions

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13. *See* Robert W. Adler, *Addressing Barriers to Watershed Protection*, 25 ENVTL. L. 973, 991-94 (1995); Craig Anthony (Tony) Arnold, *Introduction: Integrating Water Controls and Land Use Controls: New Ideas and Old Obstacles*, *in* WET GROWTH: SHOULD WATER LAW CONTROL LAND USE? 1, 34-49 (Craig Anthony (Tony) Arnold ed., 2005) [hereinafter WET GROWTH] (addressing problems of fragmentation in integrating land use, water use, and water quality controls).

14. *See* Bradley C. Karkkainen, *Collaborative Ecosystem Governance: Scale, Complexity, and Dynamism*, 21 VA. ENVTL. L.J. 189, 226-33 (2002) (describing situations in which cooperative solutions are likely to emerge, and distinguishing the incentive structures from those of open-access commons).

15. *See, e.g.*, Freyfogle, *supra* note 11, at 325-26 (noting, *inter alia*, the costs of transactions and the problems of free riders and holdouts); *see also* Barton H. Thompson, *Tragically Difficult: The Obstacles to Governing the Commons*, 30 ENVTL. L. 241, 256-65 (2000) (exploring reasons why resource users fail to embrace solutions to open-access commons problems).

16. Holly Doremus, *Crossing Boundaries: Commentary on "The Law at the Water's Edge,"* *in* WET GROWTH, *supra* note 13, at 271, 295-312 (exploring informational and institutional obstacles to decision-making that transcends existing boundaries, and suggesting improvements); Freyfogle, *supra* note 11, at 324

result both from failures to obtain and react to ecological information, and from shortsighted perceptions of self-interest.[17] The information necessary to assess and incorporate ecological values in decision-making may be costly, difficult to obtain, or difficult to understand. Information gathering and processing mechanisms within organizations may be faulty.[18] The institutional context may encourage a lack of attention to spillover effects, as, for example, when narrow legislative delegations of authority to administrative agencies limit the type of information and relevant goals to agency tasks.[19]

In this perspective, the boundary line brings about a sort of institutionalized obliviousness. The autonomous organizational actors are unable to perceive ecological information with enough precision and urgency to take it into account. This concern about inadequate ecological understanding intersects with concerns about how organizational self-interest is discerned. Determinations of self-interest rest inevitably on the consideration of available information, while motivations to gather and attend to information derive from projections of expected benefits.

B. More Property or Less?: The Search for New and Better Boundaries

When organizational decision-makers fail to perceive and respond to information about ecological repercussions beyond the lines that represent the bounds of their authority, does society need to eliminate boundary lines, or create new ones? This question amounts to asking whether there is "too much" property in existing institutional arrangements, or "not enough" property.[20] In modern controversies over transboundary ecosystems, both assertions are, in a sense, true. On the one hand, existing boundaries may seem to reflect and solidify the authority of autonomous actors to take fragmented and ecologically unwise

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(suggesting that boundaries create incentives to ignore spillover effects, and that a proliferation of boundaries increases the problem).

17. *See, e.g.*, Dale D. Goble, *The Property Clause: As if Biodiversity Mattered*, 75 U. COLO. L. REV. 1195, 1196-99 (2004) (fragmentation created by boundaries fosters myopic decisions that fail to consider landscapes as whole ecosystems).

18. The insularity of experts created by their professional specializations can also contribute to the shortsightedness of the entities to which they provide information. WET GROWTH, *supra* note 13, at 35-36; Richard B. Norgaard & Paul Baer, *Collectively Seeing Complex Systems: The Nature of the Problem*, 55 BIOSCIENCE 953, 953-54 (2005); Sharachchandra Lélé & Richard B. Norgaard, *Practicing Interdisciplinarity*, 55 BIOSCIENCE 967, 968-69 (2005).

19. *See* Karkkainen, *supra* note 14, at 205 (discussing effects of narrow agency missions); Robert B. Keiter, *Beyond the Boundary Line: Constructing a Law of Ecosystem Management*, 65 U. COLO. L. REV. 293, 318 (1994) (describing legislative mandates of federal agencies that create obstacles to integrated ecosystem management initiatives).

20. Carol M. Rose, *A Tale of Two Rivers*, 91 MICH. L. REV. 1623, 1627 (1993) (reviewing JUAN DE ONIS, THE GREEN CATHEDRAL: SUSTAINABLE DEVELOPMENT OF AMAZONIA (1992) and THEODORE STEINBERG, NATURE INCORPORATED: INDUSTRIALIZATION AND THE WATERS OF NEW ENGLAND (1991)). For a recent exchange of differing views on the "too-much-property or not-enough-property" debate, see Robert W. Adler, *The Law at the Water's Edge: Limits to "Ownership" of Aquatic Ecosystems*, *in* WET GROWTH, *supra* note 13, at 201, and Doremus, *supra* note 16.

actions without taking external effects into account. This observation points toward a need to find ways of transcending the fragmentation represented by existing boundaries, in order to manage ecosystem resources "as a whole" on behalf of a community of people that likewise extends across organizational lines.

Conversely, a diagnosis of a "tragedy" also logically leads to a demand for boundary creation.[21] If fragmented jurisdictions cause common pool resources to be wastefully exploited without attention to important ecological values, then some sort of resource management system needs to be created that can take the overlooked ecological values into account, and thus control exploitation.[22] This amounts to a demand for configuring a property regime that has effective means for regulating the use of available resources among members of a redefined community, while excluding incompatible encroachment at a redesigned periphery. In short, the real problem might not be "too much" property, but in fact, not enough.[23]

What might be the structure of a newly devised property regime? One frequent suggestion is that boundary lines ought to be redrawn so that jurisdictional boundaries of the management organization coincide with the structure of ecological phenomena.[24] If ecological degradation stems from a "mismatch" of integrated ecosystems with the fragmented boundaries of human decision-making institutions, then, as the suggestion goes, the boundaries of natural resource management institutions should be reconfigured to mirror the scope of ecological interconnections and the full range of environmental repercussions.[25] Notably, this commentary suggests that boundary lines may

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21. *See* Fennell, *supra* note 12, at 910 (noting that unifying property interests to overcome problems of fragmentation in the management of complex interdependent resources requires fracturing other interests that might otherwise be bundled together).

22. *See* Hanna, Folke, & Mäler, *supra* note 1, at 9 (asserting that property regimes provide critical means for coordinating human with natural systems so as to protect ecosystem dynamics).

23. Rose, *supra* note 20, at 1627. *See also* Carol M. Rose, *Property in All the Wrong Places?*, 114 YALE L.J. 991, 1019 (2005) (reviewing MICHAEL F. BROWN, WHO OWNS NATIVE CULTURE? and KAREN R. MERRILL, PUBLIC LAND AND POLITICAL MEANING: RANCHERS, THE GOVERNMENT, AND THE PROPERTY BETWEEN THEM (2002), and noting that newly-evolving property rights can provide means for protecting and expressing relationships of people to resources and to each other).

24. *See e.g.*, Lance H. Gunderson, C.S. Holling & Stephen S. Light, *Barriers Broken and Bridges Built: A Synthesis*, *in* BARRIERS AND BRIDGES TO THE RENEWAL OF ECOSYSTEMS AND INSTITUTIONS 489, 526-27 (Lance H. Gunderson et al. eds., 1995) [hereinafter BARRIERS AND BRIDGES]; *see also* Timothy H. Profeta, *Managing Without a Balance: Environmental Regulation in Light of Ecological Advances*, 7 DUKE ENVTL. L. & POL'Y F. 71, 97 (1996).

25. *See* Bradley Karkkainen, *Marine Ecosystem Management & A "Post-Sovereign" Transboundary Governance*, 6 SAN DIEGO INT'L L.J. 113, 116-20 (2004) (discussing scale mismatches and recommending strategies for matching forums to the scale and nature of the resources); *see also* James Salzman, *Creating Markets for Ecosystem Services: Notes from the Field*, 80 N.Y.U. L. REV. 870, 881-82 (2005) (discussing institutional obstacles to creating new institutions that stem from the lack of alignment between political and ecological boundaries); Cymie Payne, *The Ecosystem Approach: New Departures for Land and Water: Foreword*, 24 ECOLOGY L. Q. 619, 620 (1997) (introducing symposium themes, including issue of conflicts between natural and legal boundaries).

become impediments to ecologically wise decisions; not merely if they cut across shared resources spanning existing borders, but also if they are "too large," including people who are insufficiently interested in or knowledgeable about the resources, so that the people are poorly motivated to protect the resources.[26]

Implicit in this argument that ecosystem management institutions ought to be the "right size" are two key suggestions about improving human decision-making forums. The first suggestion is that forums for acquiring and considering ecological knowledge should be reconfigured to ensure acquisition and consideration of information that is currently ignored. That suggestion invites discussion of how knowledge gathered by scientific experts through research may be meaningfully transmitted, and how other sorts of local knowledge of ecosystems may be recognized and incorporated through inclusive decision-making processes. The second suggestion is that by redefining the relevant community to mirror the web of ecological repercussions, including a more carefully targeted range of affected interests, narrow calculations of organizational self-interest may be transformed into broader assessments of community welfare.

Whether characterized as a means for revamping the determinations of organizational self-interest, or as a means for opening decision-making processes to new information, the goal of these recommendations is to foster new forms of coordination, and to incorporate additional concerns as a basis for resource management decisions. The purpose of the re-conceived boundary line is both inclusionary and exclusionary: new "voices" and interests should be included in the decision-making, so that ecologically harmful activities can be regulated or excluded.

The notion that human governance structures should match the configuration of the natural resources they purport to address is appealing. Nevertheless, as explored in the next section, the delineation of the relevant ecosystem unit and its affiliated human members is hardly a simple matter, even when the transboundary aspects of ecological resources seem self-evident. Indeed, modern advances in the study of ecosystems have both added new conundrums to debates over the configuration of appropriate institutions, and contributed new concepts to the coordination of human and ecological dynamics.

III. THE COMPLEX GOALS OF FRESHWATER ECOSYSTEM RESTORATION

A. *Configuring Institutions to Match Ecosystems*

A river that crosses a boundary line from one jurisdiction to another may appear, at first glance, to be a single, integrated transboundary ecosystem.

26. *See* Karkkainen, *supra* note 14, at 212-17; Karkkainen, *supra* note 25, at 119 (noting that scale mismatches include situations in which a state is too large to deal effectively with environmental problems of a regional or local character).

However, the implications of the transboundary ecological connections for institutional design are not necessarily simple.[27] The ecological complexity of the river system itself gives rise to complicated questions about the appropriate scale and configuration of institutional arrangements.[28]

Efforts to coordinate uses of ecosystems through institutional arrangements must not only confront the conflicting claims of multiple human actors, but also the complex dependencies and interactions among other organisms, and the abiotic aspects of their environments. Advances in scientific research have highlighted the dynamic, multilayered, and unpredictable attributes of ecosystems. Several key observations about the dynamics of ecosystems have had important effects on recent recommendations about the wise configuration of human institutions.[29]

1. Uncertainty, Nonlinearity, and Unpredictability

The dynamics of ecosystems are sufficiently complex that predictions cannot be made with certainty. Non-linear processes mean that small changes may be magnified through feedback mechanisms, while the effects of seemingly large events may be greatly diminished. Even though equilibrium conditions may emerge, multiple equilibria are possible, and abrupt shifts from one condition to another may occur in unpredictable ways.[30] Patterns are discernible, but they are not fixed or stable. Instead of static conditions, researchers see patterns of ongoing activity and transformation, sometimes described as recurrent phases of exploitation, conservation, release (or "creative destruction"), and reorganization.[31]

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27. *See* Thomas T. Ankersen & Richard Hamann, *Ecosystem Mangement and the Everglades: A Legal and Institutional Analysis*, 11 J. LAND USE & ENVTL. L. 473, 478 (1996) (warning against "facile efforts to realign jurisdictional boundaries along ecosystem lines, without far-reaching political and institutional realignments").

28. *See* Adler, *supra* note 13, at 1093-94; Karkkainen, *supra* note 14, at 206-210; Keiter, *supra* note 19, at 294-95; *see also* Carol M. Rose, *Common Property, Regulatory Property, and Environmental Protection: Comparing Community-Based Management to Tradable Environmental Allowances*, *in* THE DRAMA OF THE COMMONS 233, 240-45 (Elinor Ostrom et al. eds., 2002) [hereinafter THE DRAMA OF THE COMMONS] (discussing implications of resource complexity).

29. *See* Fred Bosselman, *What Lawmakers Can Learn from Large-Scale Ecology*, 17 J. LAND USE & ENVTL. LAW 207, 207-21 (2002) (introducing a discussion of recent scientific developments that have implications for the configuration of legal frameworks).

30. *See* C.S. Holling & Lance H. Gunderson, *Resilience and Adaptive Cycles*, *in* PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS 25, 26 (Lance H. Gunderson & C.S. Holling eds., 2002) [hereinafter PANARCHY] (summarizing findings about episodic change and multiple equilibria).

31. *Id.* at 32-35.

2. *Multiple Scales, Semi-Autonomy, and Self-Organization*

The non-linear processes of ecological change take place at multiple scales. Relevant factors in understanding ecological change may be different depending on the scale of analysis. While ecological activity is not entirely chaotic and indecipherable, diverse patterns of change are discernible at many different levels of activity.[32] The various scales of analysis are sometimes described as "nested," or interrelated through a "hierarchy" of connections, although the reference is not to a top-down framework or central control structure, but rather to patterns of influence in multiple scales of adaptive organization.[33]

While the patterns of activity at various ecological scales are interconnected, not all ecological events are connected to each other to the same degree or in the same way. Rather, some processes support and reinforce each other to create phenomena that may be seen as relatively independent of other processes in the environment. Researchers depict semi-autonomous, self-organizing phenomena that are "loosely coupled" across scales.[34] Self-organizing processes protect and perpetuate identifiable patterns, even though these remain subject to influence and disruption by external factors.[35]

3. *Ecological Resilience and the Human Role in Ecosystems*

The human economy is significantly insulated from local environmental disruptions by various methods of storage and global transportation of goods; however, it is ultimately linked to, and dependent upon, the dynamics of ecological processes. Because the human economy and ecosystems are intertwined, long-term human welfare depends on fostering processes of ecological self-organization.[36] In this regard, human society is dependent on ecological resilience, or the capacity of ecosystems at all scales to renew their patterns of activity through self-organizing processes following disruptions.[37]

The concern in the literature on ecosystem resilience is not only that the political and property frameworks of the human economy are configured to

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32. *See* Bosselman, *supra* note 29, at 226-27 (discussing the separation of complex systems into layers and phases for purposes of analysis).

33. *See* C. S. Holling et al., *Sustainability and Panarchies*, *in* PANARCHY, *supra* note 30, at 72-74 (noting that the use of the term "hierarchy" is misleading, and recommending the adoption of the alternative term "panarchy").

34. *See, e.g.*, Bosselman, *supra* note 29, at 230-31 (describing research on self-organization).

35. Holling et al., *supra* note 33, at 69.

36. *See, e.g.*, Fikret Berkes & Carl Folke, *Linking Social and Ecological Systems for Resilience and Sustainability*, *in* LINKING SOCIAL AND ECOLOGICAL SYSTEMS: MANAGEMENT PRACTICES AND SOCIAL MECHANISMS FOR BUILDING RESILIENCE 1, 20-22 (1998) (emphasizing linkages between economic and ecological processes); Douglas A. Kysar, *Sustainability, Distribution, and the Macroeconomic Analysis of Law*, 43 B.C. L. REV. 1, 8-44 (2001) (tracing the development of concepts in ecological economics).

37. Berkes & Folke, *supra* note 36, at 11-13; Holling & Gunderson, *supra* note 30, at 27-30 (contrasting concepts of "ecosystem resilience" and "engineering resilience").

maximize efficient short-term production of commodities valued in economic transactions, but that they destroy the variations that are essential for resilient renewal of ecosystem patterns over the longer term.[38] The same market-based devices that human society uses to buffer itself from local ecological disruption and ensure the stable supply of commodities undermine the abilities of ecological communities to shift, adapt, and reorganize in the wake of changing circumstances.[39]

For example, the waterworks that divert, store, and deliver water to municipalities or agriculture at reliable rates, and thus buffer human society from flood and drought conditions, may disrupt the variations in water quantities and quality to which other organisms are adapted. The lowered water levels in a flowing river, during a period of drought, then may be so altered that ecological connections are broken, and organisms die or fail to reproduce. The rigid, commodity-oriented human system produces brittle ecosystem conditions that are subject to abrupt change. Yet, given the reliable supply of water off stream, human institutions may fail to pay attention or respond. Precipitously, the river species may disappear, replaced by very different organisms suited for survival in warm, oxygen-depleted, pond-like conditions. Such sudden switches produce new ecological conditions, but the community of organisms and the functions of the prior system are lost.

4. Adaptive Management and Institutional Learning

While the unpredictability of ecosystems means that ecosystems cannot be closely controlled, an optimistic view suggests that people can fruitfully manage their interactions with other organisms and ecological phenomena by fostering the variable processes that renew environmental dynamics, rather than maximizing production of stable streams of commodities from renewable resources. Given the complexity and uncertainties of ecosystems, this goal requires management strategies that involve ongoing learning and adjustment.[40] First, people and their organizations, in making decisions about the exploitation of natural resources, must adjust their own resource uses in adaptive ways to accommodate the patterns of ecological variation to which other organisms are

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38. C.S. Holling, *What Barriers? What Bridges?, in* BARRIERS AND BRIDGES, *supra* note 24, at 6-9.

39. *See, e.g.*, Lynda L. Butler, *The Pathology of Property Norms: Living within Nature's Boundaries*, 73 S. CAL. L. REV. 927, 968-69 (2000) (noting the effects of closely managing ecosystems to reduce variability and produce commodities). *See also* Joseph L. Sax, *Property Rights and the Economy of Nature: Understanding Lucas v. South Carolina Coastal Council*, 45 STAN. L. REV. 1433, 1442-46 (1993) (contrasting the "economy of nature" and the human "transformative economy").

40. For discussions of key institutional issues in adaptive management approaches, *see generally* Holly Doremus, *Adaptive Management, the Endangered Species Act, and the Institutional Challenges of "New Age" Environmental Protection*, 41 WASHBURN L.J. 50 (2001); Alyson C. Flournoy, *Preserving Dynamic Systems: Wetlands, Ecology and Law*, 7 DUKE ENVTL. L. & POL'Y F. 105 (1996); Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward a Bounded Pragmatism*, 87 MINN. L. REV. 943 (2003).

adapted.[41] Second, a commitment to adaptive decision-making must include a sophisticated willingness to monitor ecological conditions, and to observe and learn from experience.[42] People need to find new institutional means for "tuning in" to ecosystem dynamics--as uncertain and unpredictable as they may be--and for adjusting human activities to fit these dynamics.[43]

5. *Organizations That Are Nested or Otherwise Linked Across Scales*

We return to the central question of institutional design: what does the multi-layered, dynamic, complex ecological perspective that has been sketched above mean for the design of human resource management institutions, and for the formulation of boundary lines in particular? If pursued in depth, the call for decision-making frameworks to match ecological phenomena that change over time and occur at multiple scales is a multilayered recommendation.[44]

A relevant part of social science literature emphasizes that resource management regimes, like the ecosystems to which they are related, may be studied at multiple scales.[45] This perspective discerns analogous patterns in ecological and social forms of organization.[46] It sees people coordinating their resource management activities within semi-autonomous organizations that may be nested within, or linked across scales to, other forms of organization.[47] It seeks to understand the relationships between ecological processes and patterns of human activity, and to find out whether some forms of human organization are especially well-suited to perceiving ecological patterns and managing human activities to foster ecosystem renewal.[48] From this perspective, both large and

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41. *See* Berkes & Folke, *supra* note 36, at 21 (arguing that maintaining adaptiveness and resilience is important for social institutions as well as resources).

42. *Id.* at 21-22. The incremental, experimental approach is fundamentally a pragmatic one. *See generally*, Symposium, *The Pragmatic Ecologist: Environmental Protection as a Jurisdynamic Experience*, 87 MINN. L. REV. 847 (2003).

43. *See* A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121, 1139-44 (1994) (discussing the need for adaptive management approaches in light of pervasive problems of scientific uncertainty, and noting the implications for finality in law).

44. Fikret Berkes, *Cross-Scale Institutional Linkages: Perspectives from the Bottom Up*, *in* THE DRAMA OF THE COMMONS, *supra* note 28, at 293, 301-310; Alison Rieser, *Property Rights and Ecosystem Management in U.S. Fisheries: Contracting for the Commons?*, 24 ECOLOGY L.Q. 813, 816-17 (1997).

45. *See* Adler, *supra* note 13, at 1088-92 (recommending multiple nested scales of organization in watershed management, given the importance of both regional and local control); Karkkainen, *supra* note 14, at 222-25 (discussing "nested scales" of information and considering ways of pooling information through regional collaborative institutions).

46. *E.g.*, C. S. Holling & Steven Sanderson, *Dynamics of (Dis)harmony in Ecological and Social Systems*, *in* RIGHTS TO NATURE, *supra* note 1, at 57, 65-66 (drawing parallels between ecological and social patterns).

47. Berkes, *supra* note 44, at 295-300.

48. Carl Folke et al., *Synthesis: Building Resilience and Adaptive Capacity in Social-Ecological Systems*, *in* NAVIGATING SOCIAL-ECOLOGICAL SYSTEMS: BUILDING RESILIENCE FOR COMPLEXITY AND CHANGE 352 (Fikret Berkes et al. eds., 2003). *See also* James Wilson, *Scientific Uncertainty, Complex Systems,*

small-scale forms of coordination could be important in designing institutions that are attuned to ecological phenomena.[49]

The concept of nested organizations has prominently figured in studies of management practices of indigenous peoples and other tightly-knit local groups that are closely dependent on the resources of their immediate environments for survival.[50] These studies focused on small and local organizations in seeking to understand the factors that seem to make some communities especially adept at perceiving, fostering, and adapting to dynamic ecological patterns in an integrated fashion. These studies conclude that some long-enduring community-based management regimes succeed in limiting and adapting patterns of resource exploitation in complex ways that reflect sophisticated measures for fostering ecosystem resilience in common pool resources.[51]

In addition to a system of internal resource management norms, these systems also include effective methods for excluding persons outside the group from unauthorized exploitation of resources.[52] The management regimes are thus sometimes described as "property on the outside, commons on the inside."[53] Policing of the perimeter boundary line prevents exploitation of the resources by outsiders. Within the boundary line, the community manages resources for the benefit of the group, regulating members' resource use through enforcement of community norms that may include cultural practices and other informal means.[54]

The studies of local organizations provided concepts for understanding the activities of culturally homogeneous and tightly knit local communities.[55] They also provided a springboard for considering more broadly how the form and scale of human organizations for managing natural resources--including the configuration of organizational boundaries, and the means for developing

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and the Design of Common-Pool Institutions, in THE DRAMA OF THE COMMONS, *supra* note 28 , at 327, 352-53 (discussing importance of aligning the organization of institutions with ecosystem patterns to provide for the flow of information and foster the learning process).

49. Oran R. Young, *Institutional Interplay: The Environmental Consequences of Cross-Scale Interactions, in* THE DRAMA OF THE COMMONS, *supra* note 28, at 263, 265 (describing relevant spectrum of scales).

50. Ostrom, *supra* note 6, at 101-02 (identifying "nested enterprises" as a key characteristic of successful regimes).

51. *See, e.g.*, Fikret Berkes & Carl Folke, *Back to the Future: Ecosystem Dynamics and Local Knowledge, in* PANARCHY, *supra* note 30, at 121; Johan Colding et al., *Living with Disturbance: Building Resilience in Social-Ecological Systems, in* NAVIGATING SOCIAL-ECOLOGICAL SYSTEMS, *supra* note 48, at 163, 179-81; Johan Colding & Carl Folke, *The Taboo System: Lessons About Informal Institutions for Nature Management*, 12 GEO. INT'L ENVTL. L. REV. 413 (2000).

52. *See* Fred P. Bosselman, *Replaying the Tragedy of the Commons*, 13 YALE J. ON REG. 391 (1996) (reviewing ELINOR OSTROM ET AL., RULES, GAMES, AND COMMON-POOL RESOURCES (1994)) (discussing importance of boundary rules and limits on the number of users).

53. *See* Carol M. Rose, *The Several Futures of Property: Of Cyberspace and Folk Tales, Emission Trades and Ecosystems*, 83 MINN. L. REV. 129, 144 (1998).

54. *Id.* at 174-80 (considering community-based management regimes as a form of "limited common property").

55. The papers for this conference include informative case studies from U.S. water management experiences in the Southwest.

relationships within and across those boundaries--might affect the dynamics of ecosystems.

These studies gave impetus to efforts to discern how organizations develop capacities for astutely perceiving complex ecological information and adjusting human activities in a coordinated way to foster ecosystem resilience. They also focused attention on the possibility that various forms of joint or communal management could serve to unite disparate actors while coordinating human activities within patterns of ecosystem change. "Limited common property" regimes may be seen to include other types of organizations besides the tight-knit local groups that were the focus of early studies, which rely on informal norms to manage subsistence economies.[56] For example, common-interest residential communities and specialized resource user groups established under the umbrella of a regulatory regime might also be seen to set up integrated resource management regimes within the parameters of an organizational boundary.[57]

These views draw attention to several important topics that have a bearing on transboundary resources. First, the boundary line that seems to give rise to a transboundary conflict is not necessarily the only important boundary at issue. Just as the ecosystem itself functions at multiple scales, incorporating nested patterns of ecological interactions, so too the exploitation and management of natural resources by people is channeled (and might be further coordinated) through multiple scales of societal organization. This observation highlights the importance of discerning the influence and capabilities of smaller scale forms of both private and public organizations, even when such organizations alone do not unilaterally control all aspects of a larger transboundary conflict. Such organizations may include groups that currently do not have formal protection through law, but operate in a coordinated way through informal norms. This is a polycentric and multi-faceted perspective on relevant modes of human organization. It suggests that crucial activities and decisions may be accomplished outside the direct organizational control of government and by coordination within and among other entities, including local communities, nongovernmental organizations, and private associations.

Second, this approach highlights the importance of studying the internal dynamics, capacities, and incentive structures of self-organizing groups. It suggests a wide-ranging consideration of possible organizational forms that, like the community-based resource management regimes of the early studies, are "property on the outside, commons on the inside." These organizations provide

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56. Rose, *supra* note 53, at 139-44 (addressing "limited common property" regimes).

57. *See* Rose, *supra* note 28, at 252-53; Hanoch Dagan & Michael A. Heller, *The Liberal Commons*, 110 YALE L.J. 549, 553 (2001) (arguing that many resources might best be managed through "liberal commons" regimes that establish community rights for a limited group of owners while also guaranteeing individual members a right of exit). Among the sorts of organization that might be of particular interest in the context of restoring transboundary freshwater ecosystems are water trusts and ecosystem services markets. *See* Mary Ann King, *Getting Our Feet Wet: An Introduction to Water Trusts*, 28 HARV. ENVTL. L. REV. 495 (2004); James Salzman, *Creating Markets for Ecosystem Services: Notes from the Field*, 80 N.Y.U. L. REV. 870 (2005).

potential models for coordinating and controlling the exploitation and sharing of common pool resources within a group, while maintaining an effective external boundary to exclude outside users and detrimental uses that would interfere with managing the resources "as a whole" at a relevant scale.

Third, this perspective invites scrutiny of the extent to which particular forms of human enterprise foster or undermine ecological resilience. It encourages protecting or favoring those organizations that have been especially ingenious in navigating complex ecological phenomena. Implicitly, this approach demands evaluation of a group's social capital, including its adaptive and self-organizing capacities, to see whether it has developed coordinating mechanisms for integrating human activities with ecosystem dynamics.

Fourth, the literature on multi-scale institutional arrangements draws attention to the potentially crucial constitutive and supporting roles of national, state, and local governmental authorities in recognizing, launching, encouraging, and policing the boundaries of such forms of organization. It invites consideration of the role of larger-scale governance mechanisms in establishing ground rules to foster new forms of group self-organization in pursuit of ecological goals. Additionally, it raises difficult questions about the appropriate "vertical" linkages among different scales of organization.[58]

Finally, this perspective demands new and rather subtle understandings of independence and control. It postulates a framework premised on semi-autonomy and degrees of influence at multiple scales. This is an approach that requires looking at both inside and outside the boundaries of an organization, the dynamics of self-organization, and the external defining forces that shape connections with other semi-autonomous forms of authority.

In sum, institutional arrangements for managing common pool resources may be considered at multiple scales that coincide with the ecological resources upon which they rely. The recommendation that human institutional arrangements should be designed to match the ecosystems in which they operate stems from an effort to find structural means for adjusting human activities to accommodate, pay attention to, and foster ecological patterns. If this recommendation is accepted, then it makes sense to discern, and to make efforts to support and create organizations for coordinating human activities that operate semi-autonomously at multiple scales.

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58. Paul Stern et al., *Knowledge and Questions After 15 Years of Research, in* THE DRAMA OF THE COMMONS, *supra* note 28, at 445, 465-66, 477-78. *See also* Bradley C. Karkkainen, *"New Governance" in Legal Thought and in the World: Some Splitting as Antidote to Overzealous Lumping*, 89 MINN. L. REV. 471 (2004) (discussing "New Governance" scholarship, and noting significantly differing views within this umbrella label, particularly with respect to roles of government and coercive mechanisms in setting the stage for effective self-organization and collaboration).

B. Freshwater Ecosystems and the Goal of Ecological Restoration

So far, we have considered the challenges of effectively dealing with modern understandings of ecosystems in configuring human resource management regimes. The conference title highlights a further, related question: what special issues arise when the management goal is restoration of a freshwater ecosystem? This section considers a few of the further complexities presented by freshwater restoration initiatives.

1. Freshwater Ecosystems

Freshwater ecosystems not only provide vivid examples of conflicting human activities resulting in ecological degradation of common pool resources, but they also provide the settings for complex forms of coordination and institutional innovation. Freshwater ecosystems thus offer particularly intriguing and fruitful contexts for more generally exploring puzzling questions about how new resource management regimes may emerge to coordinate human activities with the self-organizing patterns of ecosystems.

Perhaps more than any other ecosystems, freshwater ecosystems give rise to complex competing claims among people. Fresh water is critical for human survival, as well as for the survival of aquatic organisms. Fresh water also supports a wide range of beneficial uses, including fishing, agriculture, navigation, and recreation. The potential uses of water conspicuously conflict, requiring divergent instream and offstream locations, differing water qualities, or different flow characteristics. The complexity of human and non-human interdependencies can seem especially apparent in the freshwater context.[59]

The intensity and complexity of human conflicts over freshwater resources have helped to motivate the initiatives in freshwater resource management that mark the leading edge of broader efforts to develop ecosystem-oriented property regimes. Watershed-oriented task forces, partnerships, and stakeholder groups led the way in collaborative attempts--both successful and unsuccessful--to create newly integrated forums for adaptive resource management.[60] Well before the modern era of collaborative management processes, the freshwater context offered illustrations of semi-autonomous human organizations configured to

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59. The Klamath Basin provides particularly vivid and recent illustrations of complex conflict. *See* Holly Doremus & A. Dan Tarlock, *Fish, Farms, and the Clash of Cultures in the Klamath Basin*, 30 ECOLOGY L.Q. 279 (2003).

60. *See, e.g.*, Craig Anthony (Tony) Arnold, *Polycentric Wet Growth: Policy Diversity and Local Land Use Regulation in Integrating Land and Water*, *in* WET GROWTH, *supra* note 13, at 393, 417-18 (discussing collaborative processes of watershed-based problem solving, and citing to extensive recent literature on the topic); *see generally* ADAPTIVE GOVERNANCE AND WATER CONFLICT: NEW INSTITUTIONS FOR COLLABORATIVE PLANNING (John T. Scholz & Bruce Stiftel eds., 2005) (assessing case studies of recent water management efforts in Florida).

match the structure of ecological resources.[61] In social science research, some of the main themes of community-based resource management regimes have been developed through studies of water management organizations.[62]

In U.S. law, concepts of the public trust doctrine and community-oriented obligations to ensure the sustainability of renewable resources have been more thoroughly elaborated in water law than in other areas of natural resource management.[63] Notions that the underlying renewable resource must be managed as a whole to support multiple interdependent community needs, and that private rights are usufructuary and subject to modification to serve community goals are well-established.[64]

Freshwater ecosystems also provided important examples of efforts aimed at making human organizations better able to recognize and foster the semi-autonomous, self-organizing activities of non-human organisms. Reservations and appropriations of water for instream purposes are important developments in the configuration of water management regimes, particularly when they are formulated to support self-organizing capacities of communities of organisms in rivers and wetlands, and not simply the stable production of individual species for human consumption or prescribed water levels for human recreation. Water quality standards and associated biological criteria likewise support the self-organizing capacities of aquatic life when they are adequately elaborated in regulations with concepts of ecosystem resilience in mind.[65]

Property-like allocations of water resources for the benefit of non-human organisms at least provide the potential for enhancing the ability of human forums to perceive and account for effects on ecosystem resilience at multiple scales.[66] These resource allocations, if backed by effective means of boundary enforcement by administrative agencies or non-governmental groups, provide a bridge between socioeconomic and ecological frameworks. They extend the concept of nested semi-autonomous organizations to encompass both human and non-human participants. These developments in property law, particularly as they have evolved in the freshwater context, represent significant advances in formulating institutional arrangements that coincide with ecosystem structures.

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61. *See* Rose, *supra* note 53, at 179 (noting that nineteenth century riparian law decisions effectively created common property regimes along rivers, limiting water use by riparians through a "reasonable use" standard while excluding outsiders).

62. *See* Rose, *supra* note 28, at 239 (discussing irrigation systems as leading examples of community-based resource management regimes, but noting that the management of water in irrigation systems for agricultural purposes is not necessarily linked to effective protection of broader ecosystem functions).

63. *See* Carol M. Rose, *Joseph Sax and the Idea of the Public Trust*, 25 ECOLOGY L. Q. 351, 354 (1998).

64. Sax, *supra* note 39, at 1452-53 (invoking more generally usufructuary systems of water rights as models for property rights in ecosystems).

65. *See generally* Robert W. Adler, *The Two Lost Books in the Water Quality Trilogy: The Elusive Objectives of Physical and Biological Integrity*, 33 ENVTL. L. 29 (2003).

66. The property-like characteristics of resource allocations for self-organizing ecological communities are explored further in Lee P. Breckenridge, *Can Fish Own Water?: Envisioning Nonhuman Property in Ecosystems*, 20 J. LAND USE & ENVTL. L. 293 (2005).

2. *The Conundrums of Restoration Initiatives*

Initiatives to accomplish restoration to earlier ecological patterns face even more difficult challenges than efforts to foster the existing dynamics of freshwater ecosystems.[67]

First, technical and practical obstacles abound. The unpredictable, uncertain, and nonlinear characteristics of ecosystems mean that relevant factors for achieving desired change may be unknown and especially hard to determine. Alternatively, accomplishing a return to prior circumstances may seem too costly given available societal resources.[68]

Second, if sufficiently ambitious, these initiatives often face significant political challenges when they demand sweeping revisions to longstanding allocations of resources. Of course, if a transboundary liability scheme is in place, orders for restoration of damaged resources may be available through established legal channels. But where ecological understandings are only emerging, and resource allocations have ignored ecological concerns in the past, restoration projects encounter significant barriers.[69] Restoration projects may demand a dramatic unsettling of firm human expectations premised on longstanding circumstances. The legitimacy of established forums, the finality of earlier decisions, and the security of property rights may be at issue. When efforts to return significant quantities of water to instream uses means disrupting or terminating ongoing economic enterprises, legal challenges and claims for compensation are likely to follow.

Third, to be effective, restoration initiatives tend to involve taking dramatic steps. The measures must be large-scale and sweeping enough to affect the key structuring variables of the ecosystem. The hope is to move from degraded conditions that may be self-sustaining to other desirable and resilient conditions. A danger of acting in too limited a fashion is that the restored conditions will not be resilient and self-sustaining.[70] However, more extensive measures may be well beyond the capacity and jurisdiction of any local group to pursue. Consequently, restoration projects present particularly difficult questions of how to link and coordinate decision-making across multiple scales of human organization.[71]

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67. *See generally* Robert B. Keiter, *Ecological Restoration and the Public Lands: Toward a More Natural Order*, 33 ENVTL. L. REP. 10443 (2003) (exploring both the promise and the difficulties of restoration initiatives on federal lands).

68. *See* A. Dan Tarlock, *Slouching Toward Eden: The Eco-pragmatic Challenges of Ecosystem Revival*, 87 MINN. L. REV. 1173, 1181-87 (2003) (reviewing problems that the dynamic and uncertain characteristics of ecological processes pose for ecosystem revival efforts).

69. *See* Adler, *supra* note 20, at 212-23 (providing examples of restoration plans undermined by opposition of property owners).

70. Stephen R. Carpenter & Kathryn L. Cottingham, *Resilience and the Restoration of Lakes*, *in* RESILIENCE AND THE BEHAVIOR OF LARGE-SCALE SYSTEMS 51, 64 (Lance H. Gunderson & Lowell Pritchard Jr. eds., 2002).

71. *Id.* at 65 (noting the need for new social and institutional mechanisms to achieve resilient restorations).

Despite these practical, political, and legal obstacles, restoration proposals offer intriguing questions and worthwhile topics of debate relating to the appropriate configuration of human and ecological interactions. Goal-setting and boundary-drawing are important aspects of the decision-making. Implicitly, restoration efforts not only demand significant adjustments in the roles of people and other organisms, but also changes in the identity of ecosystem participants. The question asked is not only, "what organisms are here, and who has interests in this ecological community?" But also, "who, or what, *ought* to be here?"

If orchestrated in light of modern understandings of ecosystem resilience, a restoration effort is a community-building endeavor that involves both human and non-human participants. Fostering dynamic and variable patterns of self-renewing activity and restoring a semi-autonomous, self-organizing ecological community are activities that require resource allocations and boundary lines to succeed, which, in this sense, also involve reconfiguration of institutional arrangements.

Restoration initiatives in freshwater ecosystems can thus raise complex, value-laden questions about the formulation of societal goals.[72] But they can also provide forums that are at the forefront of institutional innovations to rethink the structure of human interactions with the ecosystems on which people rely. These are situations where accomplishing change will likely depend upon allocating water resources for the purpose of enabling and protecting the self-organizing capacities of non-human organisms, while withholding or reserving these resources from conflicting human uses. The resulting institutional arrangements will be, in the broad sense, new property regimes that provide new methods for defining, monitoring, tracking, and transferring resources in ways that take ecological repercussions into account.

IV. CONCLUSION

Initiatives to restore freshwater ecosystems in transboundary contexts demand institutional innovation as well as scientific expertise and technical creativity. This discussion has sketched some of the challenges that arise in the search for workable and ecologically wise governance mechanisms to advance these proposals. Whether the boundary is a political border or a property line, fragmented jurisdictional authority can pose barriers to managing human activities with ecological repercussions in mind. The perceived obstacles to wise decision-making lead to calls for more inclusive forums that cross boundaries and conform to ecosystem lines. Yet the complex, multi-scaled, changing patterns of ecosystems pose conceptual complications in efforts to match human governance structures with ecological dynamics.

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72. Alyson C. Flournoy, *Restoration Rx: An Evaluation and Prescription*, 42 ARIZ. L. REV. 187, 201-204 (2000).

Studies of community-based resource management regimes have suggested that relevant institutional innovations may in fact occur at multiple semi-autonomous scales, which is in parallel with the "nested" structure of ecological patterns. This polycentric perspective encourages consideration of the ability of organizations at multiple scales to perceive and respond to ecological information, and to adapt to ecological variations. It also invites consideration of boundary lines as important governance mechanisms delineating forms of commons management rather than as barriers. These property regimes may help to channel human endeavors to correspond with ecosystem dynamics.

Freshwater settings engender especially complex human conflicts. The wide array of human and ecological dependencies, the conspicuous tradeoffs between competing instream and offstream uses of water, and the density of human settlements in close proximity to watercourses contribute to the intensity of the disputes, and the difficulties of integrating human socioeconomic endeavors with ecosystem dynamics. Nevertheless, freshwater ecosystems provide an especially fruitful context for elaboration of ecologically attuned governance mechanisms that hold promise as models in other settings.

Ecological restoration initiatives in transboundary freshwater systems encounter these characteristic challenges, and they also give rise to particular conundrums related to the efforts to launch new ecological communities to displace old ones. Restoration projects are disruptive, and they face significant political, legal, and practical barriers to implementation. But at the same time, they provide innovative forums for reconfiguring property regimes in light of ecological relationships. In particular, they demand new means for allocating, tracking, and protecting resources to foster the semi-autonomous, self-organizing patterns of ecosystems. Transboundary freshwater ecosystem restoration initiatives highlight the need for new boundary lines, even as they invite efforts to transcend the divisions expressed by old ones.